Field Demonstration of Military Bio-based Hydraulic Fluids Using Construction Equipment at Fort Leonard Wood

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Outline

- Background
- Military Bio-based Hydraulic Fluid Specification
- Field Demonstration and Results
- Conclusions

Background

- Hydraulic systems are an essential component of military equipment ranging from aircraft flight control systems, armored vehicle and shipboard hydraulic systems, to depot machine tools
- Common problems in these hydraulic systems are the potential for leakage and possibility of spillage of hydraulic fluid
- All military hydraulic fluids were formulated with petroleum or synthetic hydrocarbon base stock, which is not readily biodegradable. So, if spilled, hydraulic fluid may harm the environment and must be cleaned up as a hazardous waste
- Implementation of Executive Order No. 13134 on Developing and Promoting Bio-based Products and Bioenergy
- U.S. Army has issued a Bio-based Hydraulic Fluid (BHF) Specification to accept Bio-based Fluids that can be used in existing military hydraulic systems

Background (continued)

- Recently, USDA has initiated Federal Bio-based Products Preferred Procurement Program to procure bio-based products including hydraulic fluids for Federal Agencies. www. Biobased.oce.usda.gov
- This program provides preferred procurement by all Federal agencies of qualifying bio-based products that meet the performance criteria of procurement standards.
- Functional Performance is an essential criterion for usage of bio-based products in existing hydraulic systems.
- In cooperation with USDA, a field demonstration was initiated at Fort Leonard Wood to verify performance of bio-based hydraulic fluids in military construction equipment.

Projected Benefits for Bio-based Fluids

- Reduce hazardous waste by natural recycling
  - Reduce petroleum hydrocarbon contamination in landfill
  - Preserve ground water and soil
  - Reduce disposal costs of hazardous waste
  - Reduce clean up costs of soil and ground water
- Reduce petroleum consumption
- Alternative lubrication resource
- Accomplish P2 program
- Others

Military Bio-based Hydraulic Fluid Specification, MIL-PRF-32073

- Specification originally designed for use in construction equipment, bridging, some tactical vehicles, shipboard hydraulic systems, and metal tool applications, etc.
- Specification requirements developed based on specific military needs and current BHF formulation technology.
- It consists of five grades based on ISO viscosity ranges and covers all types of bio-based hydraulic fluids derived from renewable resources.
- Biodegradation test uses ASTM D 5864 and D 6139, Aerobic Aquatic Biodegradation Test Method and OECD 203 toxicity Test.
- Specification requires qualification inspection and has Qualified Product List (QPL).
- No limit on concentration of bio-based material, performance is driver.

NOT MEASUREMENT SENSITIVE

MIL-PRF-32073A,
Amendment 1
17 December 2007
SUPERSEDING
MIL-PRF-32073A
5 April 2007

PERFORMANCE SPECIFICATION

HYDRAULIC FLUID, BIOBASED

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers hydraulic fluids made with renewable resources for use in environmentally sensitive areas (see 6.1).

1.2 Classification. Hydraulic fluids are of the following grades (see 6.2):

Grade 1 – ISO VG 15
Grade 2 – ISO VG 22
Grade 3 - ISO VG 32
Grade 4 – ISO VG 46
Grade 5 – ISO VG 68

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of the list, document users are cautioned that they must meet all specified requirements documents cited in sections 3 and 4 of this specification, whether or not they are listed.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: U.S. Army Tank-automotive and Armaments Command, ATTN: AMSRD-TAR-E/CM/DM/STND, MS-268, Warren, MI 48397-5000 by letter or emailed to dami_standardization@conus.army.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at http://assist.daps.dla.mil.

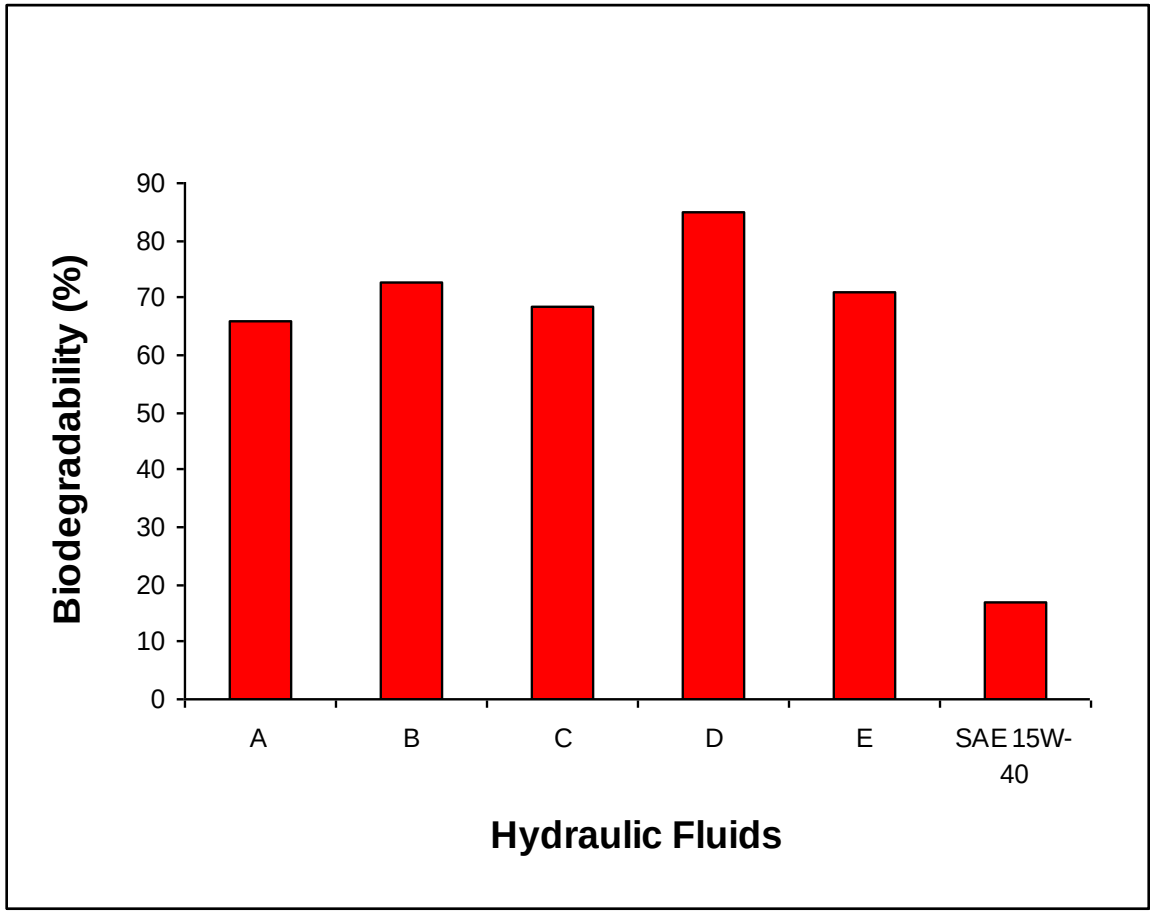
Field Demonstration

- Field tests initiated using ten pieces of construction equipment (i.e., Crane, Bulldozer, Scraper, Grader, Loader, Excavator, etc.) at Fort Leonard Wood, MO.
- Five (5) BHFs qualified under MIL-PRF-32073 Bio-based hydraulic fluid specification selected as field demonstration samples.
- Evaluation criteria used in this demonstration are their field operational performances and vehicle system compatibility such as seal leaking, and field sample evaluation.
- Evaluate Storage Stability (Shelf Life) of Bio-based Fluids.
- Duration of tests was designed for three (3) year.
- Cooperate with PM of Construction Equipment and TARDEC Construction Team.
- If field demonstration successes, fluids will be permanently introduced into military system

Bio-based Hydraulic Fluids for Field Demonstration (MIL-PRF-32073)

Code	Product name	Viscosity @40 °C	Pour point	Spec Grade	QPL Number	Company
A	Cognis Proeco EAF 422 LL	22.6	-51	2	BHF-01	Cognis
B	Novus 100 ISO 46	42.0	-44	4	BHF-02	Cargill
C	Hydro Safe ISO VG68M5	68.6	-37	5	BHF-07	Hydro Safe
D	Terresolve EL 146	46.6	-25	4	BHF-08	Terresolve
E	Hydro Safe ISO32M3B	40.3	-35	3	BHF-09	Hydro safe

Biodegradability of Hydraulic Fluids



Field Demonstration Procedure

- Fluid change over procedure

  - Operate vehicle for 15-20 minutes in order to warm the system.

  - Drain existing fluid from reservoir and total system such as pumps, lines and hoses.

  - Refill system with bio-based fluid and again operate system for 15-20 minutes.

  - At the end of the second warm-up period, drain and replace fluid with a fresh change of new fluid.

- Set up duplicate test for each fluid to increase reliability of test.
- Inspect vehicles (i.e., leaking, fluid level, power, etc) and record operation hours , and collect field samples for laboratory evaluation at each quarter of the testing period.
- Complete field demonstration after 3 years.


USED
OIL


BIO
OIL

Composition of Tested Samples in the Equipment

Equipment Code	SAE 15W-40 or MIL-PRF-2104, %	Biobased Fluid from MIL-PRF-32073, %
F-1	19.7	80.3
F-2	16.8	83.2
F-3	34	66
F-4	18	82
F-5	30.7	69.3
F-6	40.9	59.1
F-7	23.6	76.4
F-8	42.1	57.9
F-9	18.1	81.9
F-10	28.8	71.2

Field Test Results

Code	Name	Equipment Usages (hr)	Test oil	Leaking or other problems	Fluid condition (visible inspection)	Testing Periods (years)
F-1	Bulldozer	1347	A, Red	No	Good	3
F-2	Bulldozer	258	D, Green	No	Good	1
F-3	Scraper	1408	D, Green	No	Good	2
F-4	Scraper	623	E, Orange	No	Good	3
F-5	Grader	810	E, Orange	No	Good	3
F-6	Grader	1182	A, Red	No	Good	3
F-7	Loader	648	E, Orange	No	Good	3
F-8	Excavator	93	B, Blue	No	Good	2
F-9	Crane	370	B, Blue	No	Good	2
F-10	Crane	529	C, Yellow	No	Good	3

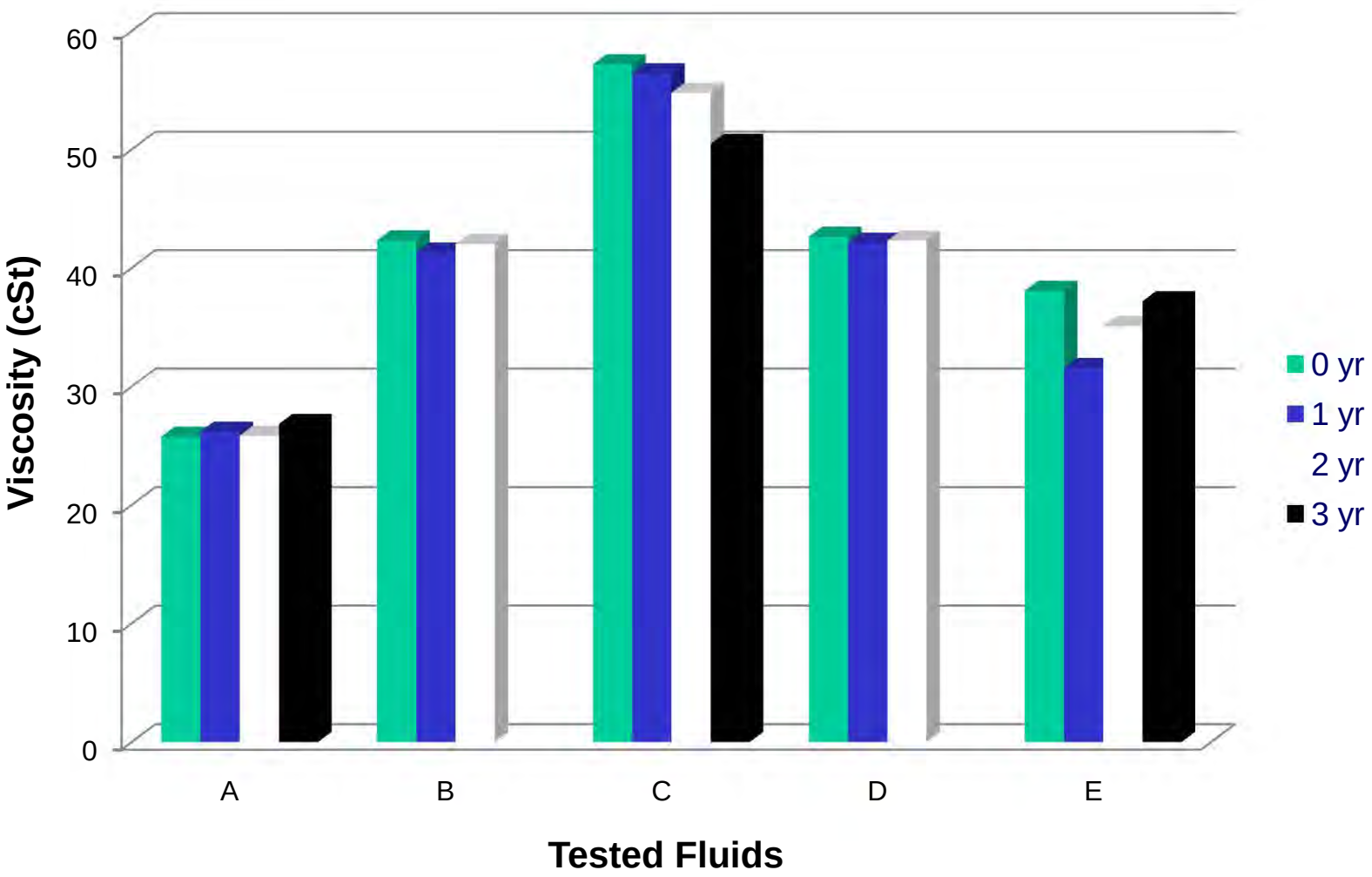
Hydraulic Piston Seal Inspection

Hydraulic Pump Inspection

Test Protocol for Laboratory Evaluation

Test	Method
Viscosity	ASTM D 445
Water content	ASTM D 6304
Oxidation Stability	ASTM D 6186, ASTM D 664
Evaporation	ASTM E 1131
Low temperature Stability	ASTM D 6351
Elemental Analysis	X-ray Technique
Composition Analysis	ASTM D 7373

Viscosity Profile of Tested Fluids



Elemental Analysis by X-ray Method

Sample ID	Concentration – ppm											
	Mg	Si	P	S	Cl	Ca	Cr	Mn	Fe	Ni	Cu	Zn
A	0	0	392	628	0	0	0	0	0	1	3	0
B	0	0	51	895	0	0	0	3	0	0	2	0
C	0	10	197	805	0	15	5	0	0	0	3	0
D	0	4	533	1090	0	0	0	4	0	0	1	0
E	0	13	117	683	0	14	0	0	0	0	1	0
SAE 15W-40	274	0	1303	4469	126	2174	0	0	3	0	0	1338
MIL-PRF-2104	0	27	1098	7000	157	2547	0	0	2	1	0	1140
F-1	0	0	236	787	0	172	0	0	0	0	5	101
F-2	0	0	324	1200	0	74	0	0	0	0	2	54
F-3	81	0	685	2247	0	545	4	0	0	0	0	325
F-4	0	0	300	1341	0	359	0	0	1	1	2	232
F-5	197	0	628	2715	465	891	0	0	7	0	45	638
F-6	156	14	535	1993	239	546	0	0	2	0	82	414
F-7	0	12	551	1988	209	806	0	0	2	0	2	464
F-8	36	0	241	1904	0	294	0	0	3	0	58	232
F-9	154	0	298	1895	0	284	0	0	0	0	40	276
F-10	280	15	480	2030	0	430	0	0	0	1	66	431

Biodegradability of Field Samples

Sample Code	Tested Sample Composition	ASTM D 7373	ASTM D 6731
F-1	A (80.3%) +P* (19.7%)	64	60.8
F-2	D (83.2%) +P (16.8 %)	66	74.8
F-3	D (66 %) + P (34 %)	59	67.3
F-4	E (82 %) + P (18 %)	55.4	57
F-5	E (69.3 %) + P (30.7 %)	49.4	ND
F-6	A (59.1 %) + P (40.9 %)	41	61.7
F-7	E (76.4 %) + P (23.6 %)	52.4	69
F-8	B (57.9 %) + P (42.1 %)	55.7	64.4
F-9	B (81.9 %) + P (18.1 %)	66.7	71.3
F-10	C (71.2 %) + P (28.8 %)	59.2	74.1
A from Drum	100% Bio-based Fluid	66	66
B from Drum	100% Bio-based Fluid	76.7	72.7
C from Drum	100% Bio-based Fluid	67	68.3
D from Drum	100% Bio-based Fluid	75.6	85
E from Drum	100% Bio-based Fluid	68	71
SAE 15W-40 from Drum	100% Petroleum Fluid	33.7	34.1
MIL-PRF-2104 from Drum	100% Petroleum Fluid	22.6	30.0

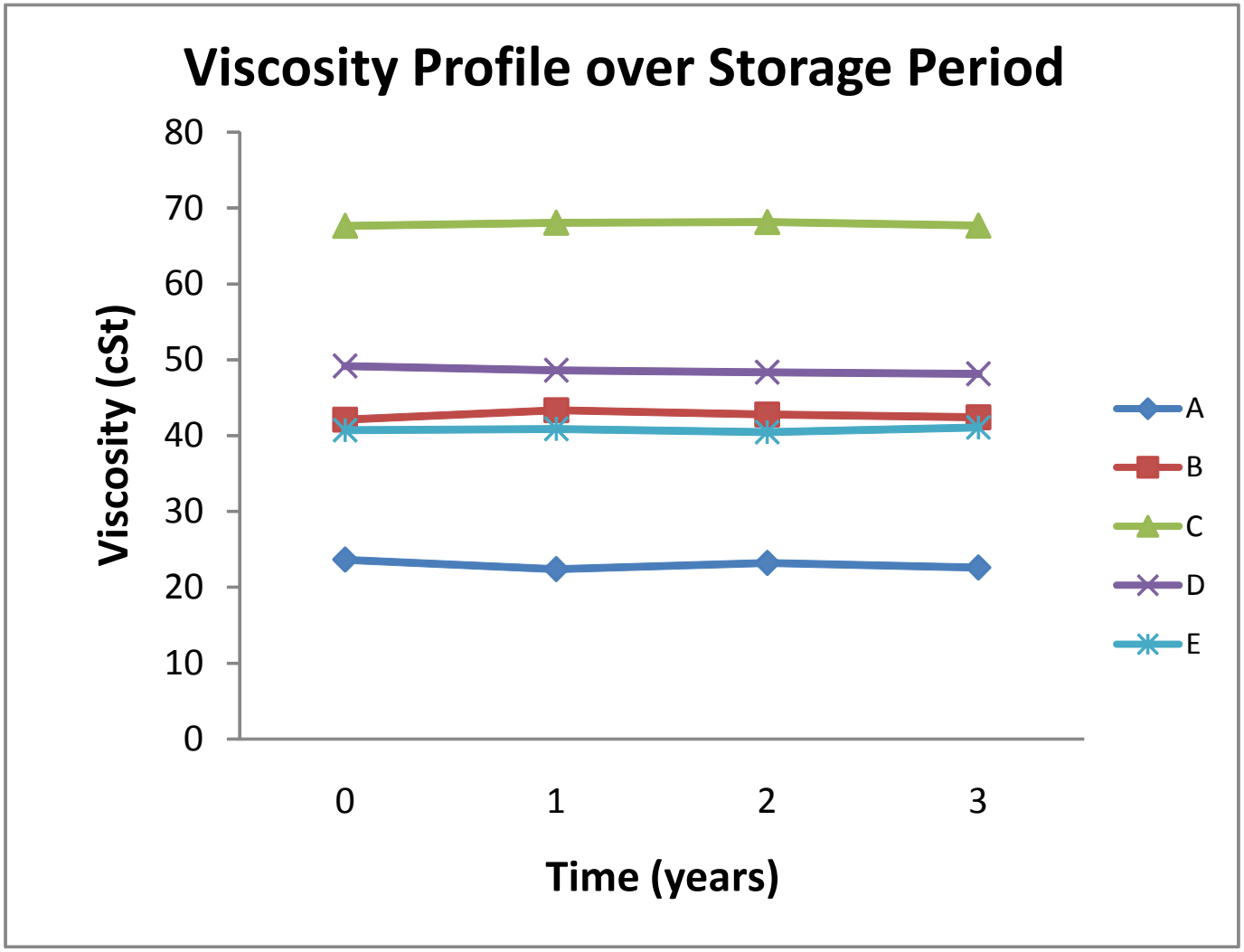
Laboratory Test Results

Test Fluid	Evaporation Change	Total Acid Number Change	Low Temp Stability Change	Total Water Content	Oxidation
A	very small	slightly	no	nil	slightly
B	very small	slightly	no	nil	slightly
C	very small	slightly	no	nil	slightly
D	very small	slightly	no	nil	slightly
E	very small	slightly	no	nil	slightly

Shelf Life Test

- Shelf life of tested fluids also determined at actual field storage conditions.
- All samples from drums collected for the laboratory tests.
- Test protocol was same as selected in field demonstration.
- Test results compared to original fluids.
- Shelf life tests conducted for three years.

Tested Fluids stored at a Shade in Fort Leonard Wood


Viscosity Profile over Storage Period
Viscosity (cSt)
80
70
60
50
40
30
20
10
0
0
1
2
3
Time (years)
A
B
C
D
E

Shelf Life Test Results

Test Fluid	Evaporation Change	Total Acid Number Change	Low Temp Stability Change	Total Water Content	Oxidation PDSC
A	no	no	no	no	very slightly
B	no	no	no	no	very slightly
C	no	very slightly	no	no	very slightly
D	no	no	no	no	very slightly
E	no	no	no	no	very slightly

Summary of Laboratory Evaluation (1)

- No significant viscosity changes observed in any construction Equipment.
- All samples showed some degree of oxidation, but still have good conditions.
- None of fluids had Low Temperature Operational Problem at Midwest Winter Weather (subzero to -30 ºC).
- BHFs had good hydrolytic stability that resists reaction with water.
- Equipment had no leaking problem, seals look good.

Summary of Laboratory Evaluation (2)

- BHFs did not give any volatility problem during demonstration.
- No evidence for incompatibility between BHFs and structural materials used in hydraulic systems.
- No Biodegradation occurred in hydraulic systems.
- Environment property of fluids (i.e., biodegradability) did not change throughout demonstration.
- No incompatibility was observed between bio-based fluids and petroleum based fluids.
- No property changes of tested fluids in storage.

Conclusions

- Field demonstration has completed using five MIL-PRF-32073 bio-based fluids and ten types of construction equipment at Fort Leonard Wood, MO.
- Field test results indicated that bio-based fluids did not show any abnormal behavior nor incompatibility with hydraulic systems such as oil leaking or operational problem.
- In addition, laboratory results from field samples indicated only normal degradation during demonstration period as compared to petroleum products.
- Bio-based fluids are compatible with existing petroleum based fluids. Fluids can be interchanged without major cleaning effort.
- Bio-based fluids did not change their properties for three years of storage periods. Their shelf life are longer than three years.
- Bio-based fluids can be used in military construction Equipment. Performance is the same as Petroleum based fluids.

Transition from Petroleum based Hydraulic Fluids to Bio-based Fluids

- Recommended to Military Construction Equipment Managers to use Bio-based fluids as military alternative operational fluids for Construction Equipment.
- This recommendation is in process within Army.